Analysing urban surface material compositions with spaceborne imaging spectroscopy data at 30 m spatial resolution

Marianne Jilge [1,2], Hannes Feilhauer [4], Uta Heiden [1],
Carsten Neumann [3], Carsten Jürgens [2]

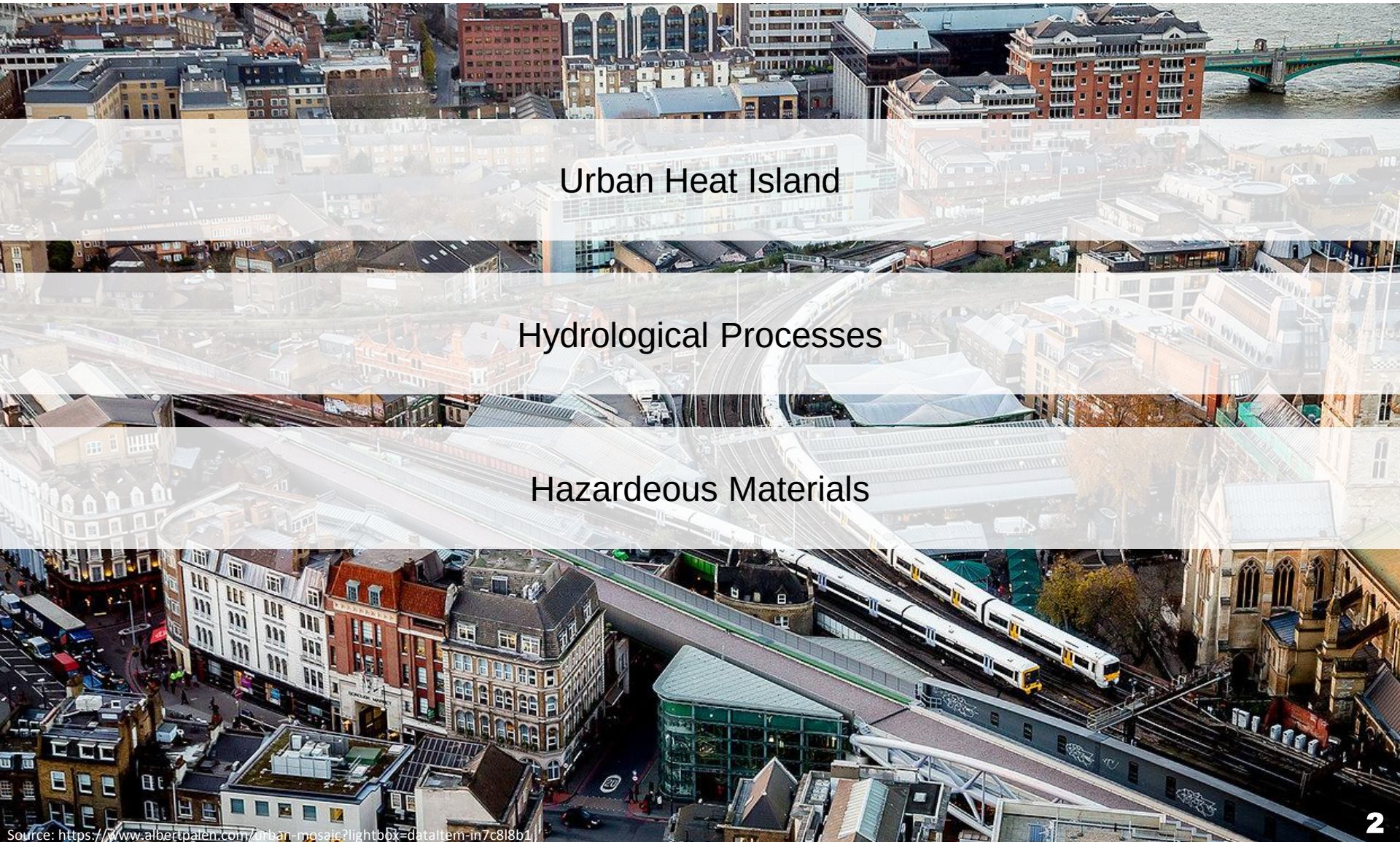
2 RUHR UNIVERSITÄT BOCHUM RUB

4 FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

1 DLR

GFZ Helmholtz-Zentrum POTSDAM 3

Why urban surface material composition?



Urban Heat Island

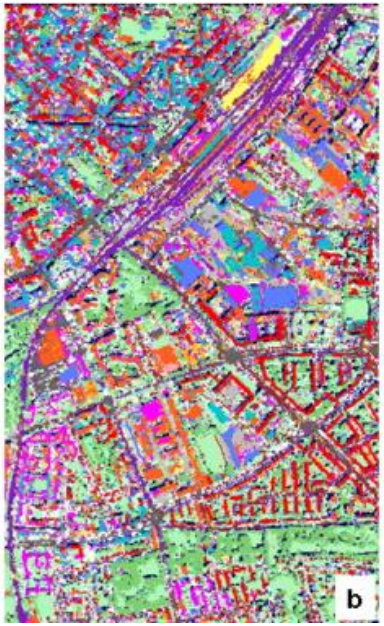
Hydrological Processes

Hazardeous Materials

Source: https://www.albertpalen.com/urban-mosaic?lightbox=dataItem-in7c8l8b1

Challenges using imaging spectroscopy data

Airborne (4 x 4 m)

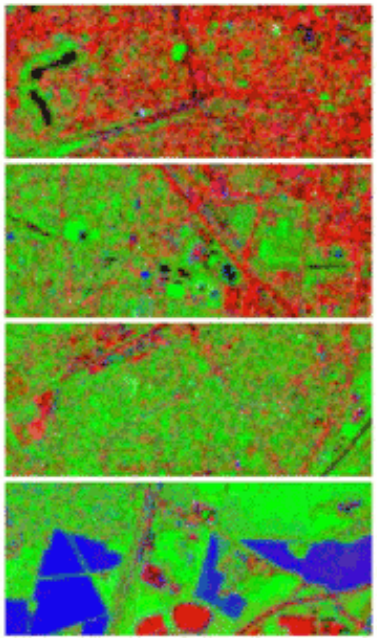


e.g.
Roessner et al. 2001
Segl et al. 2003
Franke et al. 2009
Heiden et al. 2012
Demarchi et al. 2014
Priem & Canters 2016

Modified from
Heiden et al. (2012)

Detailed material mapping:
20-40 classes

Spaceborne (30 x 30 m)



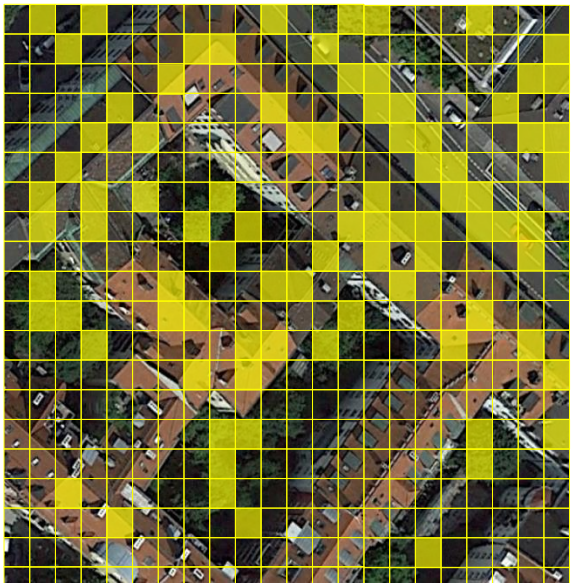
e.g.
Weng and Lu, 2008
Duca and Del Frate, 2008;
Demarchi et al, 2012
Roberts et al. 2012
Fan and Deng, 2014
Okujeni et al. 2015
Zhang, 2016
Rosentreter et al. 2017

Modified from
Okujeni et al. (2015)

Mapping of broad categories:
Vegetation – Imperviousness – Soil (VIS)

Challenges using imaging spectroscopy data

Airborne (4 x 4 m)



- Spectrally pure pixels

Spaceborne (30 x 30 m)

- No spectrally pure pixels

Surface material compositions - Urban areas


a) High density block development


b) Perimeter block development


c) Regular block development


d) Row house development


e) Detached and semidetached houses


f) High rise buildings


g) large halls and storage buildings


h) Small halls and storage buildings

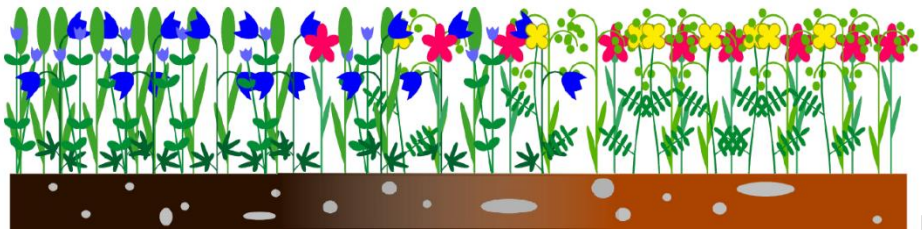

i) Parks

- Urban areas are formed by history, function and use (WITTIG ET AL., 1998, GILBERT, 1994; MAIER ET AL., 1996)
- Neighborhoods with specific structural and compositional characteristics (SUKOPP & WITTIG, 1998)
- „Typical“ surface material composition (Bochow et al. 2007, Heldens 2010)
- **„Typical“ spectral mixtures in 30 m EnMAP pixels?**

Source: Heldens, 2010; Heiden et al. 2012

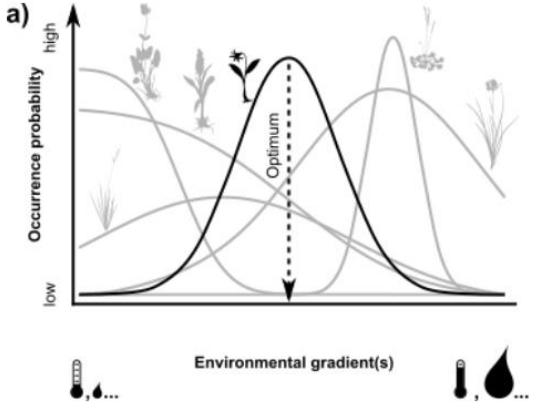
Surface material compositions – Gradient method

Natural Ecosystem

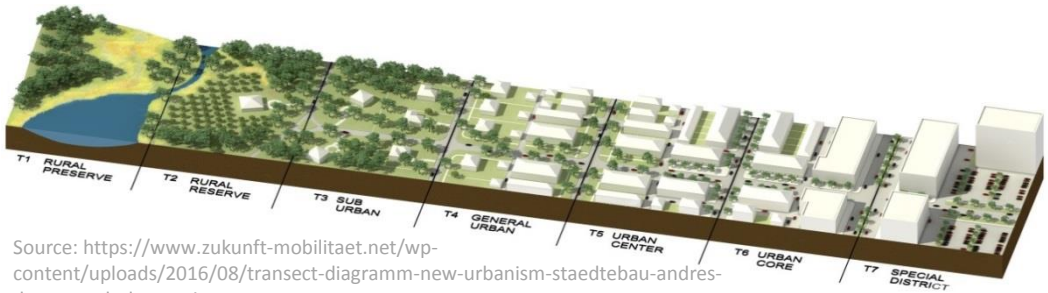


Feilhauer, 2016

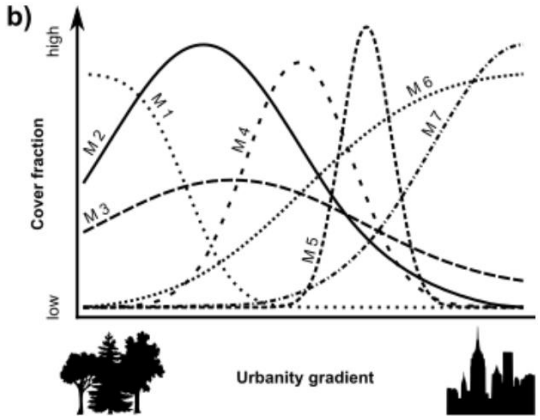
- fuzzy continuum of typical mixtures along gradients
- Optimum occurrence based on environmental conditions



Urban Areas



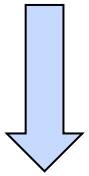
Source: https://www.zukunft-mobilitaet.net/wp-content/uploads/2016/08/transect-diagramm-new-urbanism-staedtebau-andres-duany-stadtplanung.jpg



Source: Jilge et al. (in review)

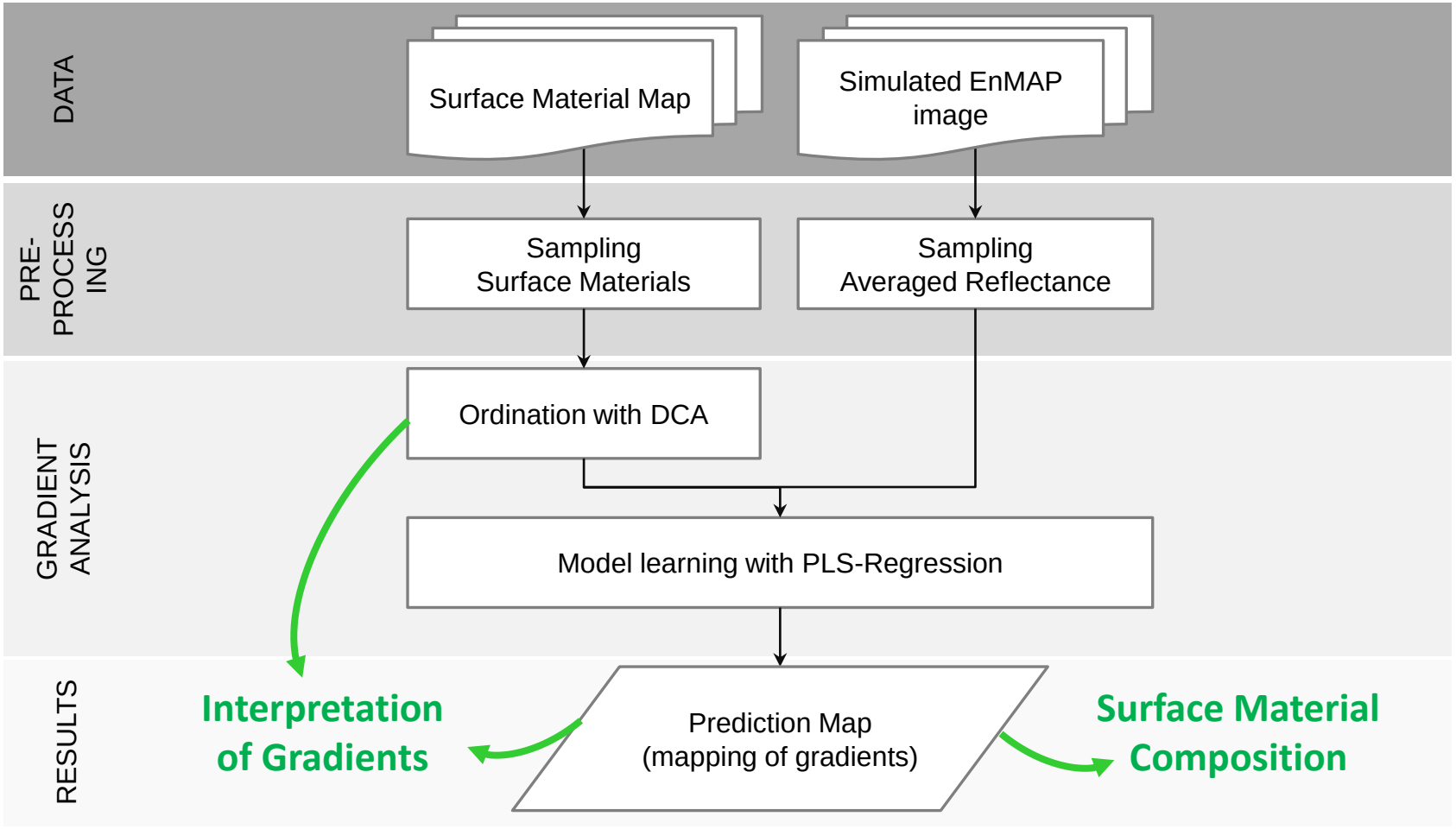
Objectives

- Are there gradual transitions in the occurrence of urban surface materials so that the gradient concept can be applied?
- Can these material gradients be associated to spectral patterns and can their spatial distribution be mapped with imaging spectroscopy data with 30 m spatial resolution?
- How can these spectral patterns be used to retrieve urban material compositions?



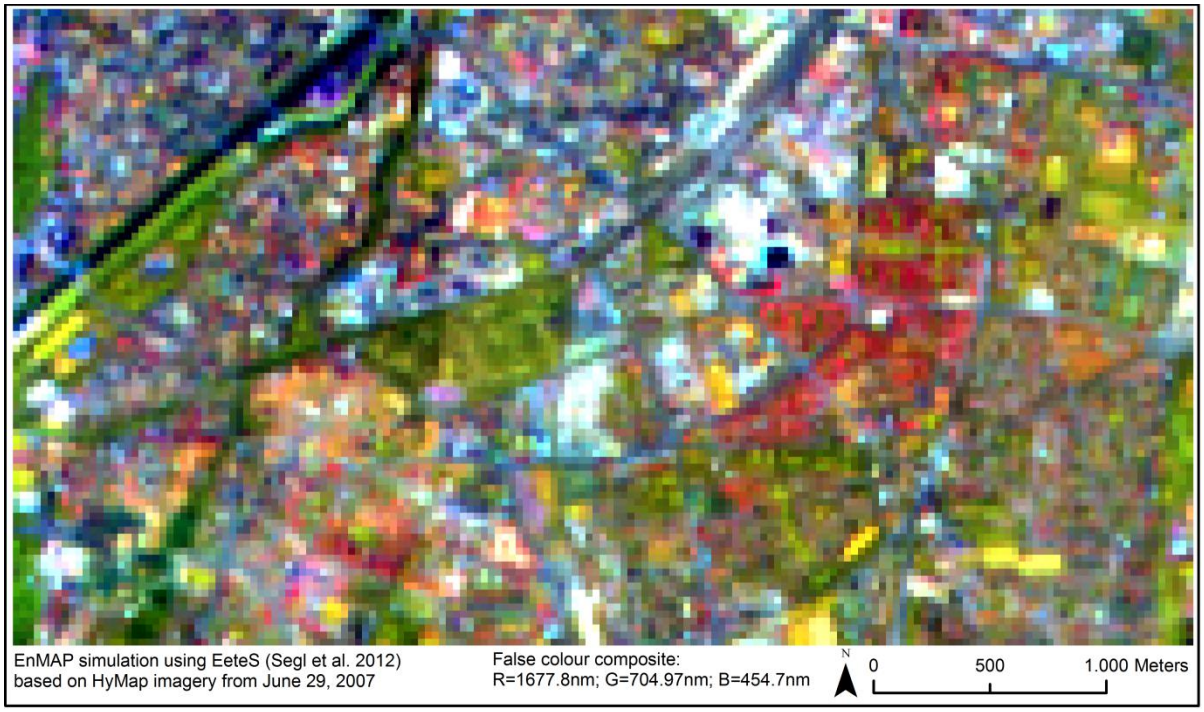
Proof of concept study in Munich, Germany

Methodology - Gradient Analysis



Source: Jilge et al. (in Review.), modified

Data – Simulated* EnMAP Data



Source: Jilge et al. (in Review)

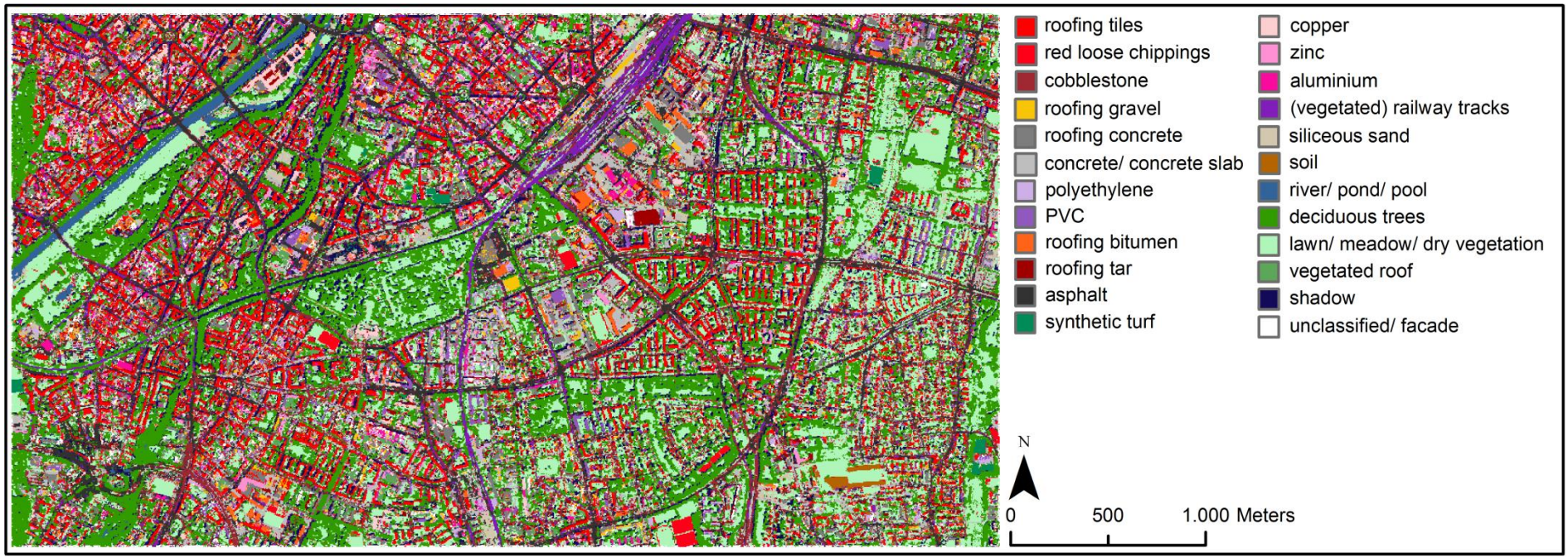
Munich, Germany

EeteS-EnMAP simulation*
from 4 m HyMap data

- 30 x 30 m pixel size
- 242 spectral bands
- 423 to 2439 nm wavelength range

** Segl, K., Guanter, L., Rogass, C., Kuester, T., Roessner, S., Kaufmann, H., Sang, B., Mogulsky, V., Hofer, S., (2012). EeteS-The EnMAP End-to-End Simulation Tool. In IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Vol. 5, No. 2, pp. 522-530*

Data – Surface Material Map

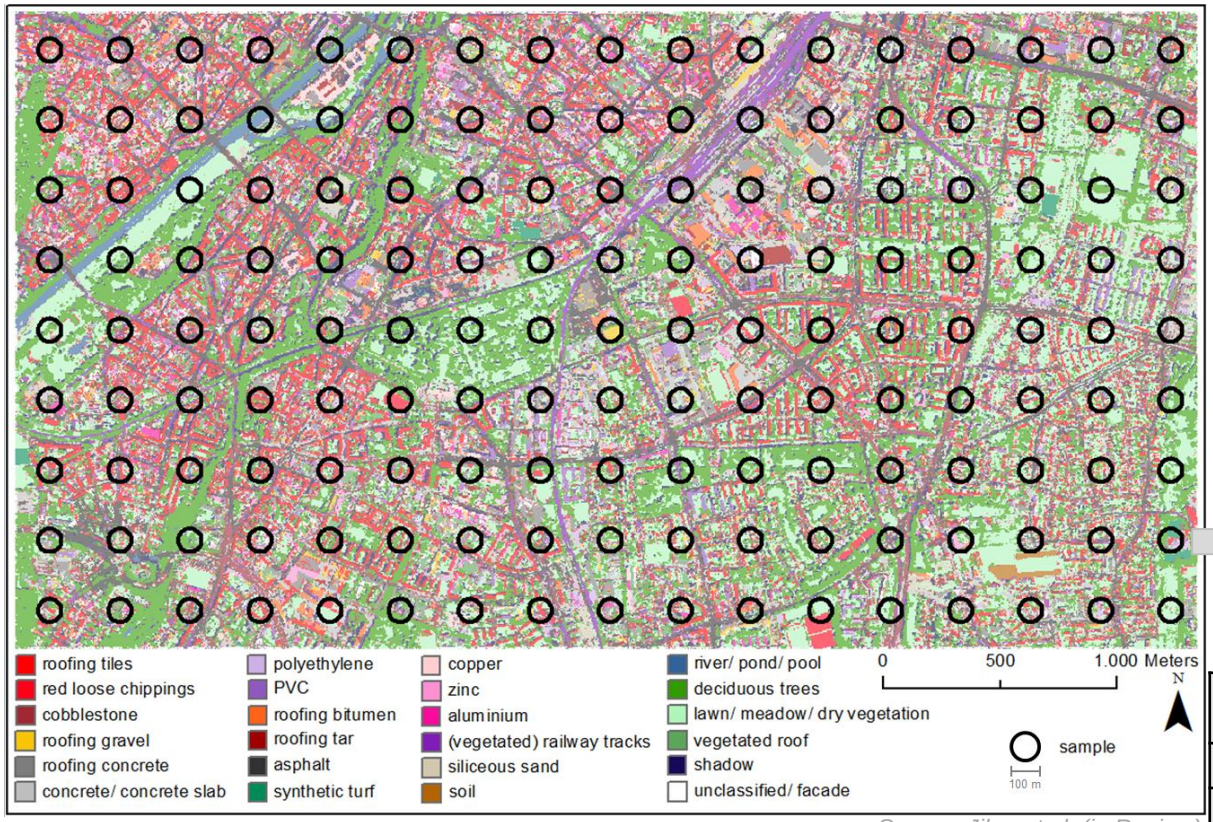


- detailed surface material map acquired from HyMap data

  (see HELDENS 2010 & HEIDEN ET AL. 2012)

- 27 classes of surface materials

Results – Sampling of Material Compositions



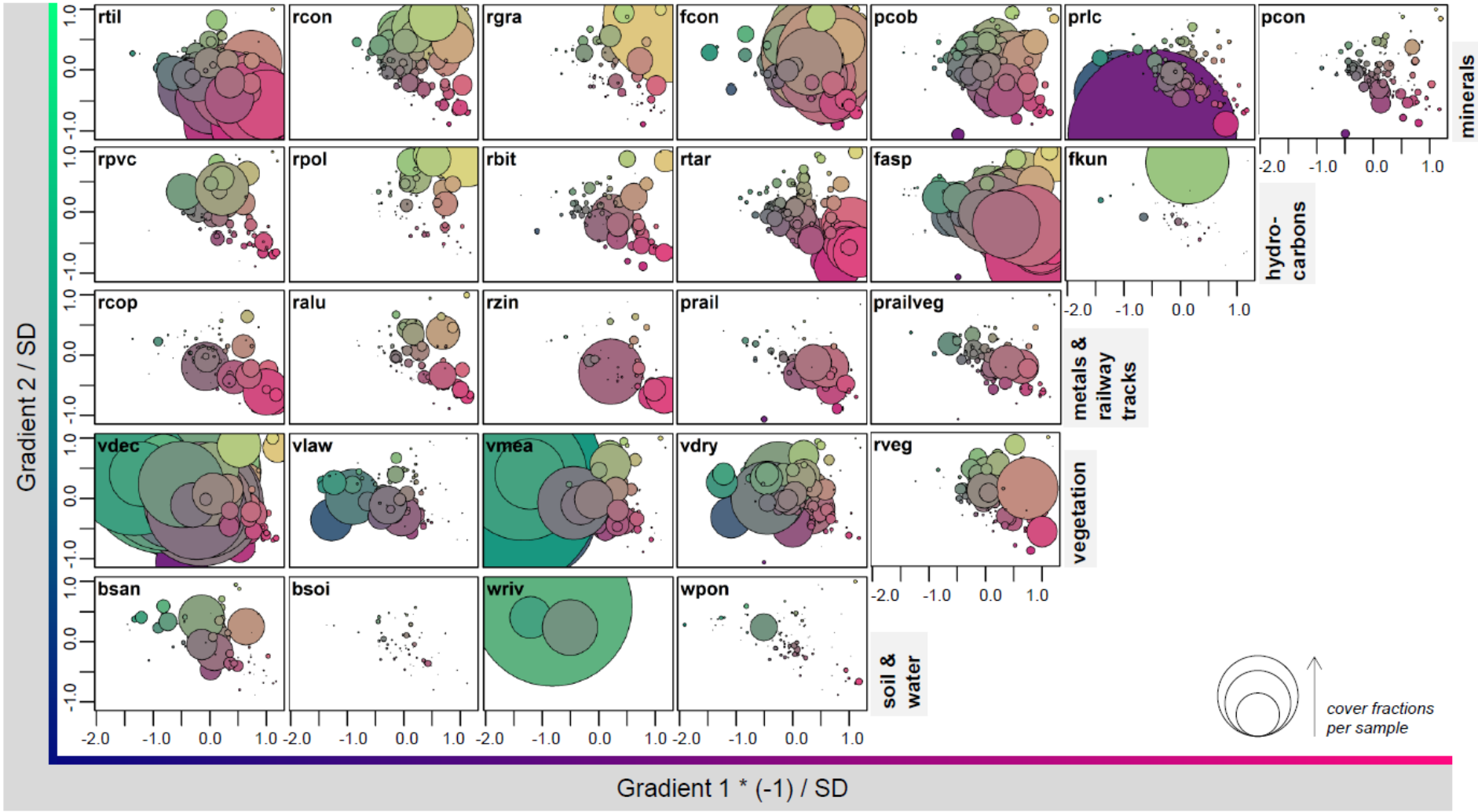
Source: Jilge et al. (in Review)

- systematic sampling grid
- 153 circular polygons (⌀ 100 m)
- inter-distance of 300 m
- cover fractions per sample listed in material table
- 4-26 surface materials per sample

Material Table of Samples

Material [n] Sample ID	Material [1]	Material [2]	…	Material [27]
1	5	15	…	2
2	10	31	…	15
3	0	0	…	19
…	…	…	…	…
153	23	29	…	1

Results - Ordination with DCA

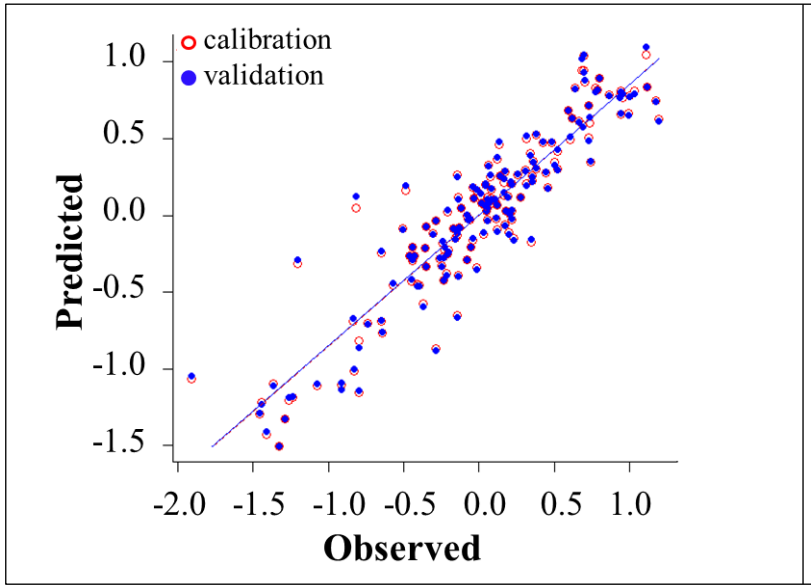


Source: Jilge et al. (in Review)

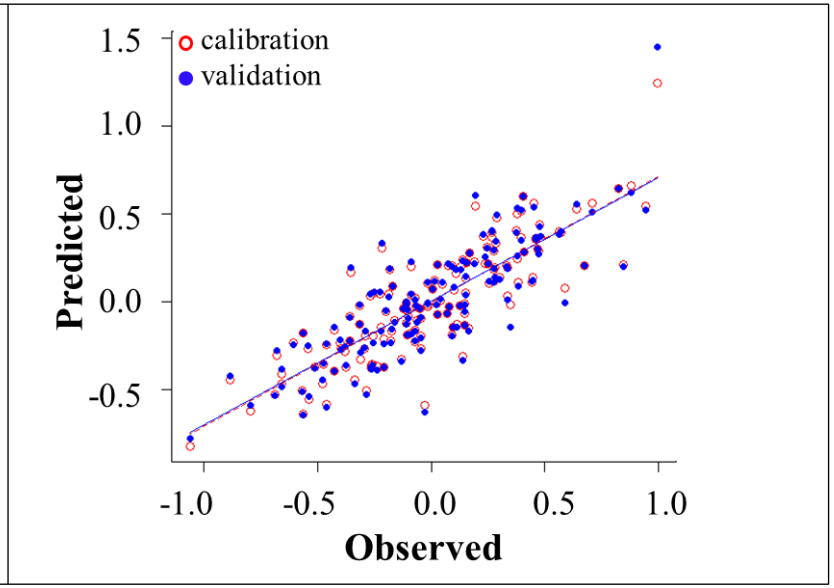
Results - Regression modelling

- regression of gradient scores against averaged EnMAP reflectance using Partial Least Square Regression (PLSR)
- 10 fold cross-validation results in R^2=0.85 (Gradient 1) and R^2=0.71 (Gradient 2)
- models used for spatial prediction of DCA scores in image data

Gradient 1

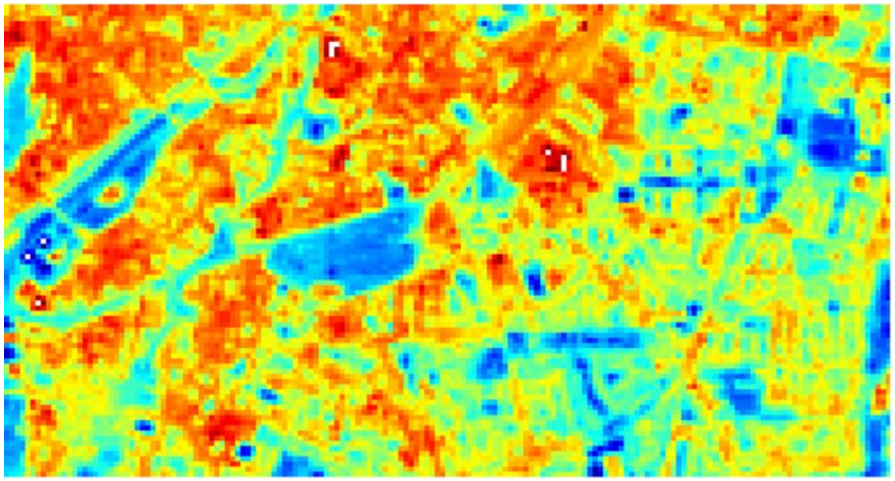


Gradient 2



Source: Jilge et al. (in Review), modified

Results - Prediction of gradient scores for Gradient 1



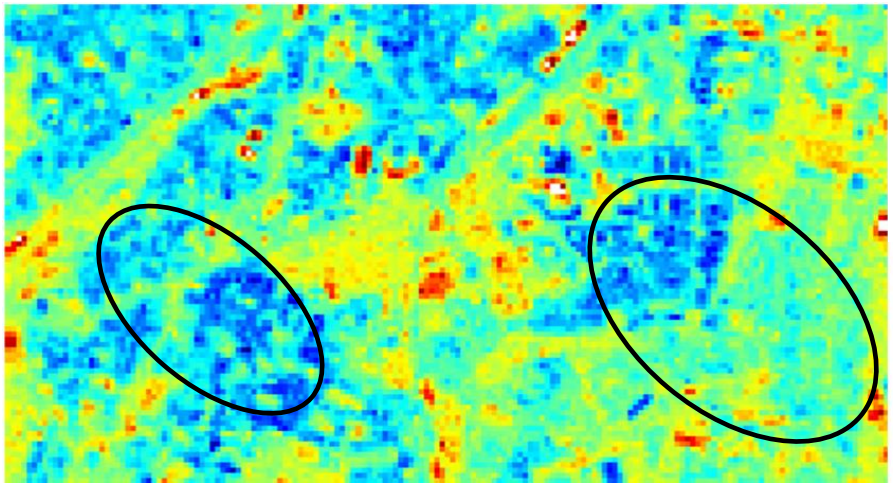
N 0 500 1000 m

Source: Jilge et al. (in Review), modified

Gradient 1: rural-to-urban

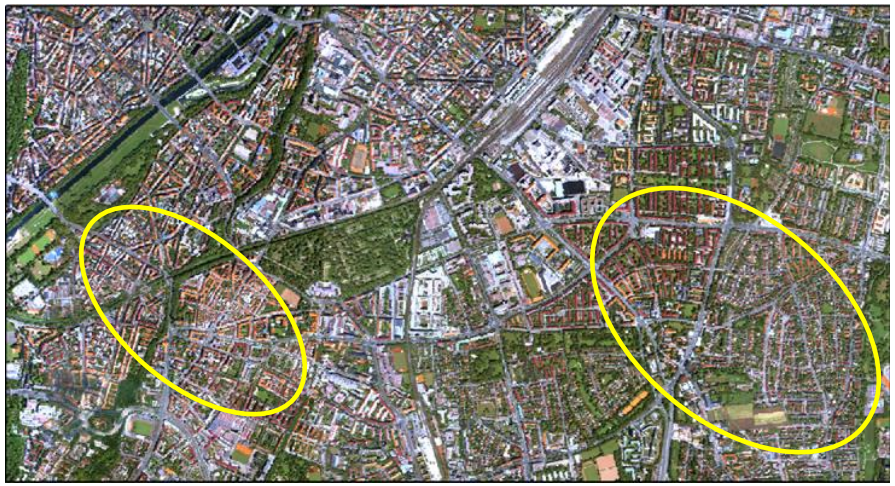
- Formation of patterns based on specific material composition
- Blue – Dominance of vegetation
- Yellow/red – Dominance of artificial materials
- Material compositions indicate an increasing imperviousness

Results - Prediction of gradient scores for Gradient 2



N 0 500 1000 m

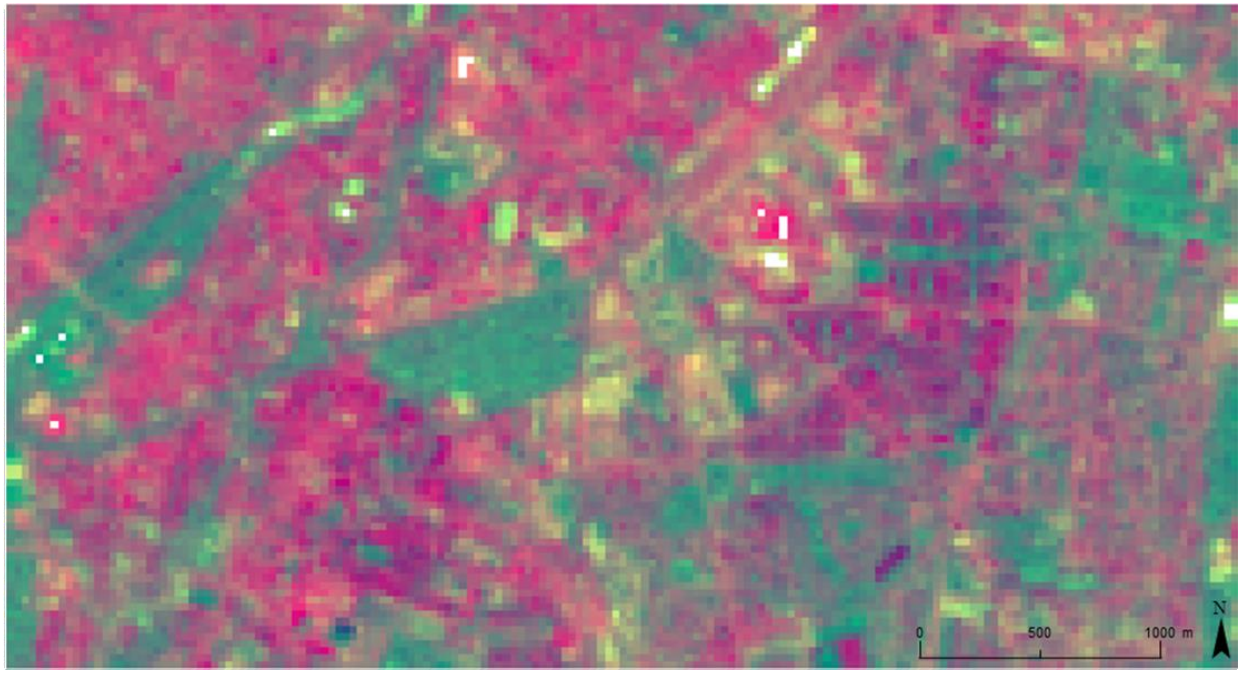
Source: Jilge et al. (in Review), modified



Gradient 2: structural details

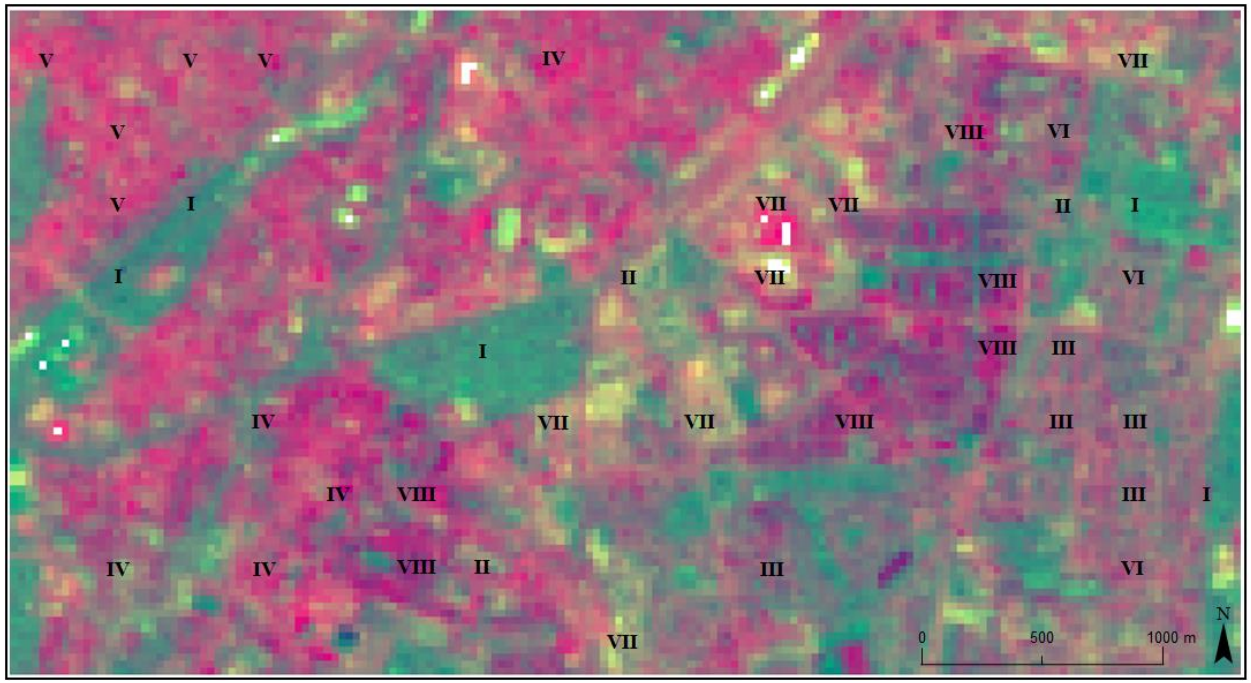
- „new“ patterns indicate different information
- Different gradient scores for built-up areas that show structural differences
- Link between material composition and structural details
- No clear brighness gradient observable

Results – Combined Prediction Map



- different material composition marked by different color shades
- colored patterns correspond to Vegetation (green) – Industry (yellow) – Residential areas (red)
- **Typical spectral mixtures in urban neighborhoods exist**

Results – Combined Prediction Map



Source: Jilge et al. (in Review), modified

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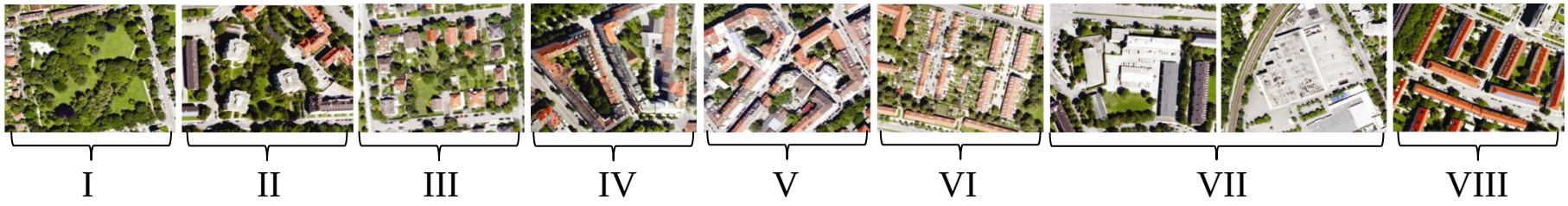
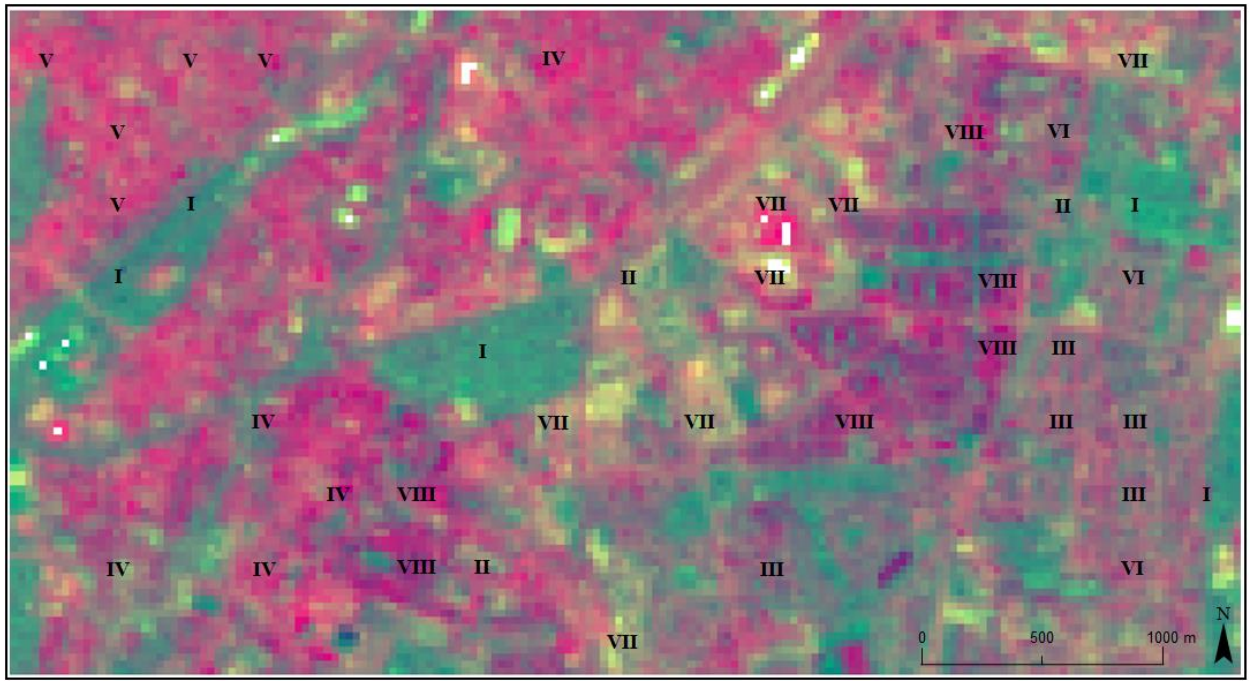
Source: Heldens, 2010; Heiden et al. 2012; modified

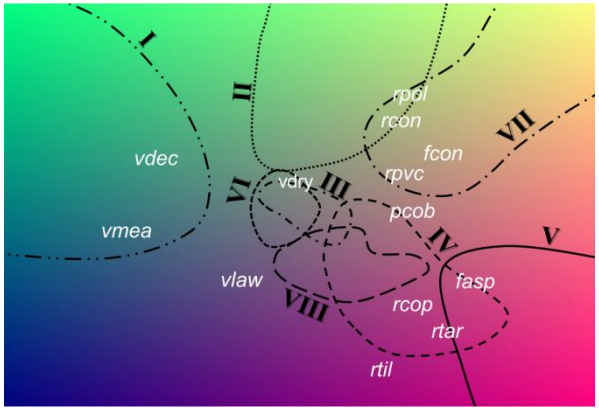


Results – How are urban neighboorhoods composed?

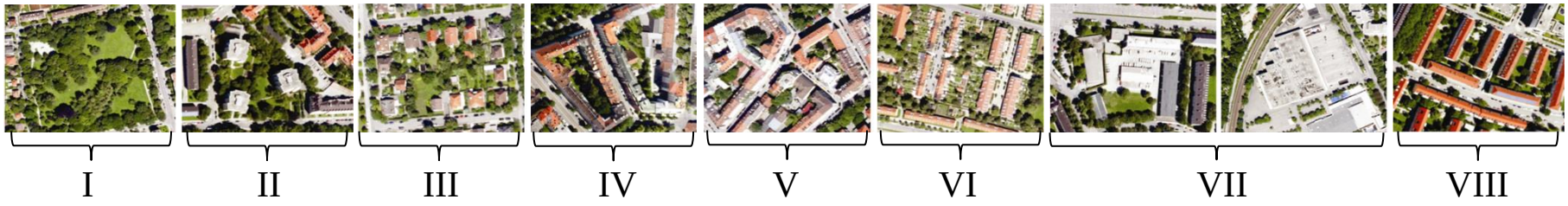


Source: Jilge et al. (in Review), modified

1. **Deliniation of urban neighborhoods in the colors legend**



Source: Heldens, 2010; Heiden et al. 2012; modified



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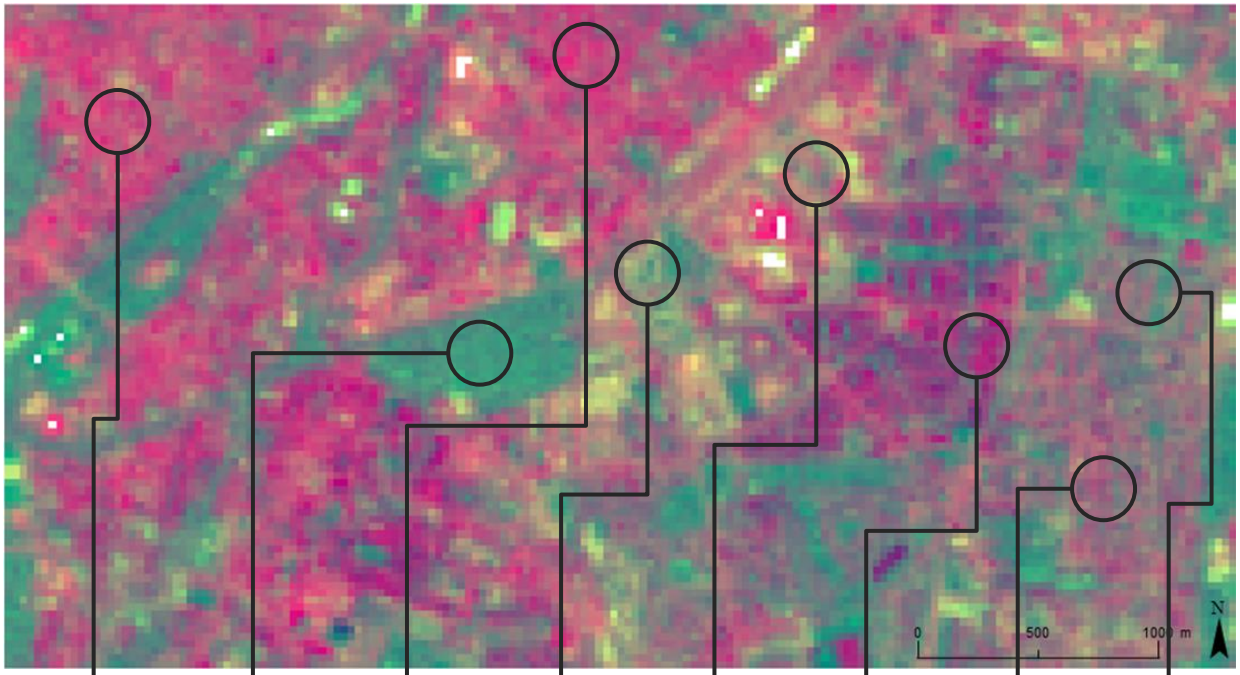
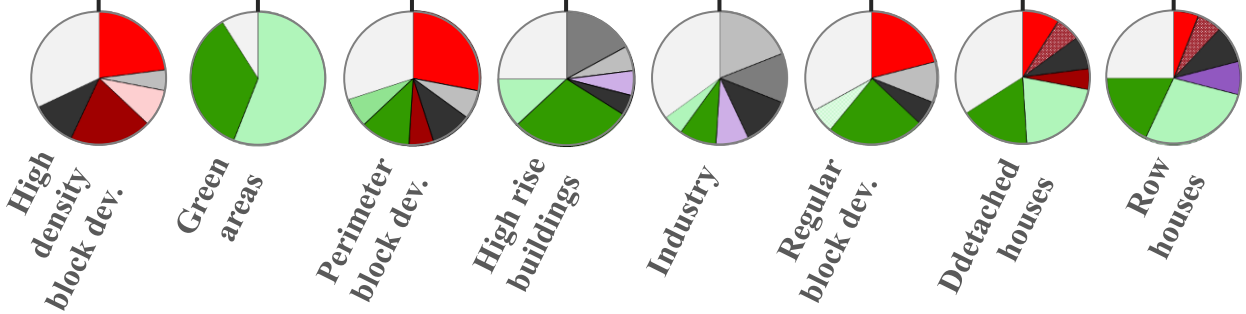
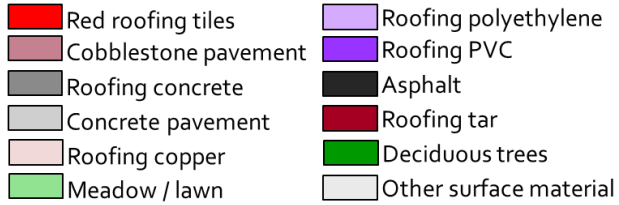


1. **Deliniation of urban neighborhoods in the colors legend**

2. **Statistical analysis of dominant surface materials**





Conclusion + Outlook

- ✓ Determination of material gradients from a heterogeneous urban environment
- ✓ Mapping urban material compositions from 30 m spatial resolution
- ✓ Urban neighbourhoods are delineated by characteristic material compositions
- ✓ Alternative classification of urban areas for spaceborne imaging spectroscopy data
- ✓ No spectrally pure endmembers are necessary to interpret complex spectral mixtures

- Transferability of results to other / larger urban areas?
- Robustness of gradient interpretation and regression models?

Thank you for your attention!

Marianne.jilge@dlr.de

http://www.coeser.de/impressions/bilder/hua-hin-06-colored-rooftops-bunte-hausdaecher-christian-oeser.jpg

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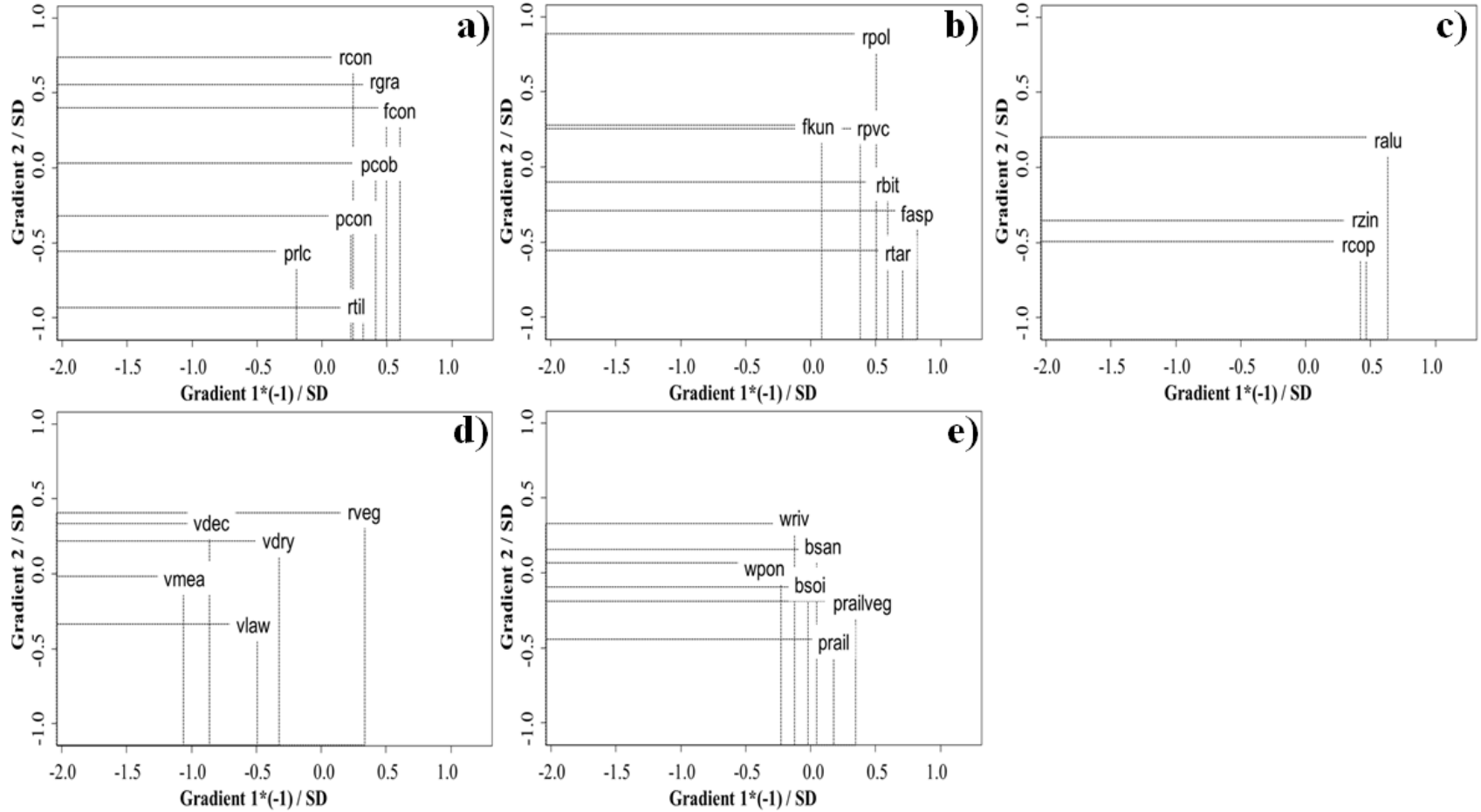
Sampling

Material Group	Surface Material	Abbreviation	Total pixels in surface material map	Sampled Cover Fractions in [%]
Minerals	roofing tiles	rtil	66886	9.2%
	roofing concrete	rcon	27440	7.4%
	roofing gravel	rgra	8206	11.1%
	concrete	fcon	42104	10.2%
	concrete slabs	pcon	11015	8.7%
	loose chippings	prlc	20546	10.7%
	cobblestone	pcob	47358	8.5%
Metals	copper	rcop	13366	8.6%
	zinc	rzin	7607	8.0%
	aluminium	ralu	10466	8.5%
Hydrocarbons	PVC	rpvc	13434	8.2%
	polyethylene	rpol	8625	9.2%
	roofing bitumen	rbit	14883	8.3.%
	roofing tar	rtar	29249	8.8%
	asphalt	fasp	84854	8.1%
	synthetic turf	fkun	3209	9.1%
Vegetation	deciduous trees	vdec	172784	8.1%
	lawn	vlaw	16983	8.7%
	meadow	vmea	87525	8.9%
	dry vegetation	vdry	35690	8.9%
	vegetated roof	rveg	18879	8.0%
	siliceous sand	bsan	11765	8.9%
Soil and Water	humous soil	bsoi	2978	6.0%
	river	wriv	4518	10.7%
	pond	wpon	4691	8.5%
Railway tracks	railway tracks	prail	10811	7.2%
	vegetated railway tracks	prailveg	11546	8.1%
			Σ 787418 (100%)	Ø 8.7%

Biplot scaling

- Determination of maximum material occurrences -



DLR